Planting Date Affects Production and Quality of Grass Pea Forage

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ABSTRACT

The rising cost of commercial nitrogen fertilizers indicates that additional research is needed concerning agronomic practices required to integrate legumes into cereal-based cropping systems. This study examined how planting date affects the productivity of grass pea (*Lathyrus sativus* L.) in central Oklahoma. Experimental plots (3 by 20 m, $n = 3$) were disked and fertilized with 60 kg P_2O_5 ha^{-1}, and inoculum-treated (*Rhizobium leguminosarum)* seeds ('AC-Greenfix') were planted at 60 kg ha^{-1} on 15 March, 1 April, and 15 April in 2004, 2005, and 2006. Biomass, N concentration, N accumulation per hectare, and in vitro digestible dry matter (IVDDM) of grass pea forage were determined on samples collected at 7 d of the year (DOY) after planting. Significant ($P < 0.05$) interactions occurred in response of biomass (DOY × year), N concentration, and IVDDM (DOY × year × planting date), and accumulated N (DOY × year; DOY × planting date). Peak biomass in 2004, 2005, and 2006 was 3900, 5800, and 3500 kg ha^{-1}, respectively. Maximum accumulated N related to years was 115 to 157 kg ha^{-1} between DOY 165 and DOY 195. Peak N accumulation of 125 to 153 kg ha^{-1} occurred between DOY 180 and DOY 210. Grass pea is flexible in response to spring planting dates, indicating that it can be sown as a green manure or forage crop during a 30-d period in the southern Great Plains and still maximize biomass and N accumulation.

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Abbreviations: DM, dry matter; DOY, day of year; FRV, fertilizer replacement value; GDD, growing degree days; IVDDM, in vitro digestible dry matter; SGP, southern Great Plains.

Rising costs of inorganic fertilizers has renewed interest in legumes for cropping systems in the southeastern United States and the U.S. Great Plains (Franzluebbers, 2007; Kirschenmann, 2007). Legumes can provide many benefits to cereal-based cropping systems. Planting a legume in rotation with cereal crops improves soil properties (McVay et al., 1989), including infiltration of precipitation into the soil profile (Daniel et al., 2006). More important, legumes biologically fix atmospheric N_2, which is available to the legume and subsequent nonlegume crop, reducing the need for inorganic N fertilizer (Badaruddin and Meyer, 1994: Beckie et al., 1997; Rao et al., 2005b).

Research in the northern Great Plains has focused on partially replacing summer fallow in cereal grain systems with annual legumes for ground cover, green manure, or forage (Badaruddin and Meyer, 1989; Badaruddin and Meyer, 1994; and Biederbeck et al., 1993). Recent research on potential candidates for use as green manure or grazing in the southern Great Plains (SGP) has been conducted (Rao et al., 2005a,b, 2007). Among the grain legumes tested in both regions, grass pea (*Lathyrus sativus* L.) has been noted for its tolerance to dry conditions and adaptability to difficult environments (Nygaard and Hawtin, 1981; Biederbeck et al., 1993). Grass pea is widely grown in western Asia and eastern Africa for both human consumption and livestock fodder

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(Chowdhury, 1988; Campbell, 1997). It has high yield potential and N contents and is grown as an alternative to fallow periods in many cropping systems of the world (Osman and Nersoyan, 1986; Campbell, 1997). Gowda and Kaul (1982) reported forage yields of 7 to 10 Mg ha^{-1} in Bangladesh when interseeded with maize (*Zea mays* L.). Early-spring planted grass pea has produced >6400 kg ha^{-1} dry matter (DM) by 75 d after planting, with N concentrations of 23 to 55 g kg^{-1} in the SGP (Rao et al., 2005b). Planting grass pea into bermudagrass (*Cynodon dactylon* Pers.) pastures allowed forage quality to exceed that of forage produced on pastures receiving 90 kg ha^{-1} N fertilizer (Rao et al., 2007).

Proper agronomic practices for growing this little known legume in the SGP must be described to capture potential benefits. Although levels of production in this region can be high (Rao et al., 2005b), the effect of planting date on plant growth of grass pea has not been defined. Investigating this fundamental agronomic practice may lead to improved management strategies for cultivating grass pea. The objectives of this work are to define the optimum seeding dates for DM production of grass pea and the seasonal N accumulation in SGP, as well as the influence of seeding date on forage quality.

MATERIALS AND METHODS

This study was conducted during the spring and summer growing seasons in 2004, 2005, and 2006 at the USDA-ARS, Grazinglands Research Laboratory near El Reno, OK (35°40′ N, 98°00′ W, elevation 414 m). Soils on the study site were described (USDA-NRCS, 1999) as Dale silt loams (fine-silty, mixed, superactive, thermic Pachic Haplustolls). Average maximum and minimum temperatures during March through July were 25 and 16°C, respectively. Long-term (1971–2000) average precipitation during this period was 485 mm.

The grass pea cultivar AC-Greenfix was planted in three replicate sets of experimental plots that were divided into nine subplots (3 by 20 m). Plots were cultivated and had 60 kg P_2O_5 ha^{-1} applied in the last week of February each year of the study. No N fertilizer was applied during the experiment. Seeds were treated with a commercial liquid inoculum of *Rhizobium leguminosarum* (Lipho Tech., Inc., Milwaukee, WI) and planted at 60 kg ha^{-1} in 60-cm rows, to provide approximately 15 to 20 plants m^{-1} row. Plantings were undertaken on three dates (15 March, 1 April, 15 April ± 2 d) of each year, and applied planting dates were repeated on the same sub-plots throughout the study. Rainfall and ambient temperature at the site were monitored throughout the experiment. Growing degree days (GDD) were calculated [$(T_{max} + T_{min})/2 - 0°C$] for each day.

Aboveground samples were collected at 15-d intervals from 45 to 135 d after seeding from plots under each planting date. Three, randomly selected 0.5-m row lengths were clipped from each plot at a 25 mm height from a new location, on each sampling date. Plant samples were dried in a forced-draft oven at 65°C until constant weights were obtained to quantify aboveground crop biomass, and ground to pass a 1-mm screen. Samples were analyzed for N concentration using a complete combustion N analyzer (Leco CHN-1000, Leco Corp., St. Joseph, MI) and in vitro digestible dry matter (IVDDM) by the two-stage technique of Tilley and Terry (1963), as modified by Monson et al. (1969).

Logarithmic transformations of crop biomass, N concentration, amount of accumulated N per hectare [kg ha^{-1} biomass × (% N/100)] and IVDDM were analyzed by mixed model procedures with planting date and years evaluated as fixed effect and average day of year (DOY) (related to days after seeding) the longitudinal (repeated) effect (Littell et al., 1996; Patetta, 2005). Logarithmic transforms were used to correct non-normal distributions of data in their original scales (Steel and Torrie 1980). Despite the repeated application of treatments to plots during the study, years were included in the models as fixed effects. Tests for compound symmetry (Mauchly's test criterion, W′) undertaken during exploratory analyses found no autocorrelation among years for crop biomass ($W' = 0.86$; $\chi^2 = 3.2$; $P = 0.20$), N concentration ($W' = 0.94$; $\chi^2 = 1.3$; $P = 0.52$), N accumulation ($W' = 0.87$; $\chi^2 = 2.8$; $P = 0.24$) or IVDDM ($W' = 0.93$; $\chi^2 = 1.5$; $P = 0.46$). Days after seeding (as DOY) were analyzed with spatial power variance/covariance matrices, given the form of changes in level of covariance among sampling dates, and uneven spacing between dates. The LSMEANS procedure was used to test for differences in significant main and interaction effects, and values were reported in their original scales after back-transformation. Level of significance for tests was $P = 0.05$.

RESULTS

The amount and distribution of precipitation varied among and within years (Table 1). Total precipitation in 2004, 2005, and 2006 was 63, 78, and 61%, respectively, of the 30-yr average. On average, the largest amounts of precipitation were recorded in May (excluding 2004) and June. Precipitation received from dates of planting to physiological maturity was also below the long-term average for those sections of the growing season (Table 2). Growing conditions during all three years could be described as drought affected, with dry periods recorded during March through May of 2004 and 2005, and May through July 2006. Ambient temperatures during all three years deviated ± 2°C or less from the site averages (USDA-NRCS, 1999). Growing degree days to flowering was variable for planting dates during the three years (Table 3). In contrast, there were fewer calendar days to flowering (9–14 d) and maturity (5–29 d) for the later planting dates.

Main effects for crop biomass related to planting date ($F_{2,102} = 1.3$; $P = 0.28$), and years ($F_{2,102} = 2.4$; $P = 0.09$) were not significant, while effects related to DOY ($F_{1,19.4} = 110.0$; $P < 0.01$) were. The interaction between DOY and years was also significant ($F_{2,103} = 3.0$; $P = 0.048$). The greatest amounts of biomass (Fig. 1) were produced on DOY 197 and DOY 213 of 2005 (5200 and 5600 kg DM ha^{-1}). A diverse assemblage from the remaining last three dates of all three years produced a group with the second-highest biomass. Although similar over DOY 120 and DOY 135, biomass did not accumulate in a similar fashion over the remainder of the growing seasons. Crop biomass in 2004 increased to 3900 kg (DM) ha^{-1} over 90 d (May through late July); to 5800 kg (DM) ha^{-1} over 75 d (May through early July) in 2005; and to 3500 kg (DM) ha^{-1} over 60 d (May through June) during 2006.

Three-way interaction effects between planting date, years, and DOY on N concentration were significant (Fig. 2). The highest N concentration in grass pea forage was recorded for DOY 120 for the 15 Mar. 2004 planting date (56.7 g kg^{-1}). A diverse assemblage from the three planting dates of all three years (DOY 120 to DOY 150) produced a group with the second-highest N concentrations. The lowest N concentrations (24.9 and 23.9 g kg^{-1}) were recorded for DOY 195 for the 1 Apr. and 15 Apr. 2005 planting dates. Nitrogen concentration of forage from the planting dates declined differently during the three years. In 2004 N concentration of forage collected from plots planted on all three dates declined to a consistent level (29.8 to 33.7 g kg^{-1}) over 15- to 30-d periods. In contrast, N concentration of forage collected from plots planted on 1 Apr. and 15 Apr. 2005 and 2006 displayed relatively continuous declines.

The three-way interaction between year, DOY, and planting date main effects were significant (Fig. 3). The highest IVDDM of grass pea forage (942 g kg^{-1}) was recorded for the 15 Mar. 2004 planting date on DOY 120. An assemblage of forage IVDDM from DOY 135 and DOY 150 of all years for all three planting dates produced a group with the second-highest level of digestibility (844 to 884 g kg^{-1}). Grass pea forage with the lowest IVDDM (648 and 646 g kg^{-1}) was recorded for DOY 195 of the 1 and 15 Apr. 2005 planting dates. As with N concentration, IVDDM of grass pea forage from the planting dates declined in different ways during the three years of the study. In 2004 IVDDM of forage collected from plots planted on all three dates declined to a consistent level between 743 and 769 g kg^{-1} over 15- to 30-d periods. In contrast, IVDDM of forage collected from plots in 2005 and 2006 continued to decline, with IVDDM of forage from the 15 March and 1 April planting dates showing small increases on DOY 165 (2006) and DOY 180 (2005).

Day of year × year (Fig. 4A) and DOY × planting date (Fig. 4B) interactions had significant effects on N accumulation in aboveground biomass. The greatest amount of accumulated N (Fig. 4A) within the DOY × year interaction was recorded on DOY 180 of 2005 (157 kg N ha^{-1}), while a group containing DOY 195 of 2005, and DOY 195 and DOY 210 of 2006 produced the second-highest amounts. Although amounts were similar over the first two dates of all three years, N accumulated differently over the remainder of the growing seasons. Aboveground N increased: to 136 kg N ha^{-1} over 90 d (May through late

Table 1. Mean monthly precipitation and temperature for March through July 2004 to 2006, and 30-yr average (1971–2000) at the study site.

Month	Precipitation				Temperature			
	2004	2005	2006	30-yr avg.	2004	2005	2006	30-yr avg.
	mm				°C			
Mar.	32	13	64	69	13.3	9.9	8.9	10.5
Apr.	33	7	82	76	14.7	14.7	18.4	15.2
May	04	95	76	148	21.3	19.4	21.3	20.2
June	155	174	38	125	23.1	24.9	25.1	24.8
July	82	90	40	67	25.1	25.7	28.5	27.7
Total	306	379	300	485				

Table 2. Total precipitation received from date of planting to physiological maturity of grass pea during 2004 through 2006, and 30-yr averages (1971–2000) for those sections of the growing season.

Seeding date	2004	2005	2006	30-yr avg.
	mm			
15 Mar.	224	289	235	418
1 Apr.	275	365	196	416
15 Apr.	257	358	150	492

Table 3. Growing degree days (GDD) > 0°C for flowering and physiological maturity by seeding date and year; calendar days to flowering and physiological maturity are in parentheses.

Seeding date	GDD to flowering			GDD to maturity		
	2004	2005	2006	2004	2005	2006
	d					
15 Mar.	710 (49)	772 (58)	855 (54)	2147 (113)	1933 (104)	1961 (105)
1 Apr.	688 (43)	767 (49)	795 (45)	2644 (110)	2123 (105)	1796 (91)
15 Apr.	768 (39)	879 (49)	806 (40)	2475 (108)	1916 (90)	1596 (76)

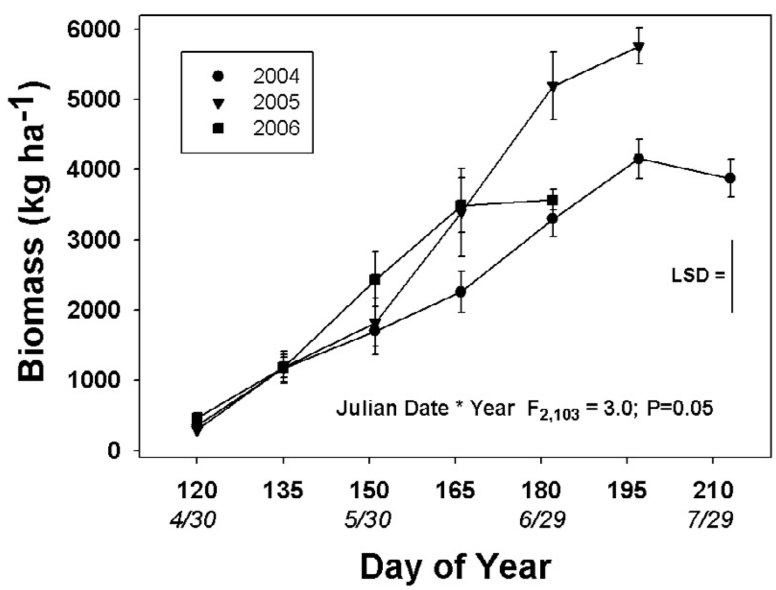

Figure 1. Dry matter yield of grass pea during the 2004 through 2006 growing seasons; calendar dates are in italics below day of year. Vertical bars are ± 1 SEM.

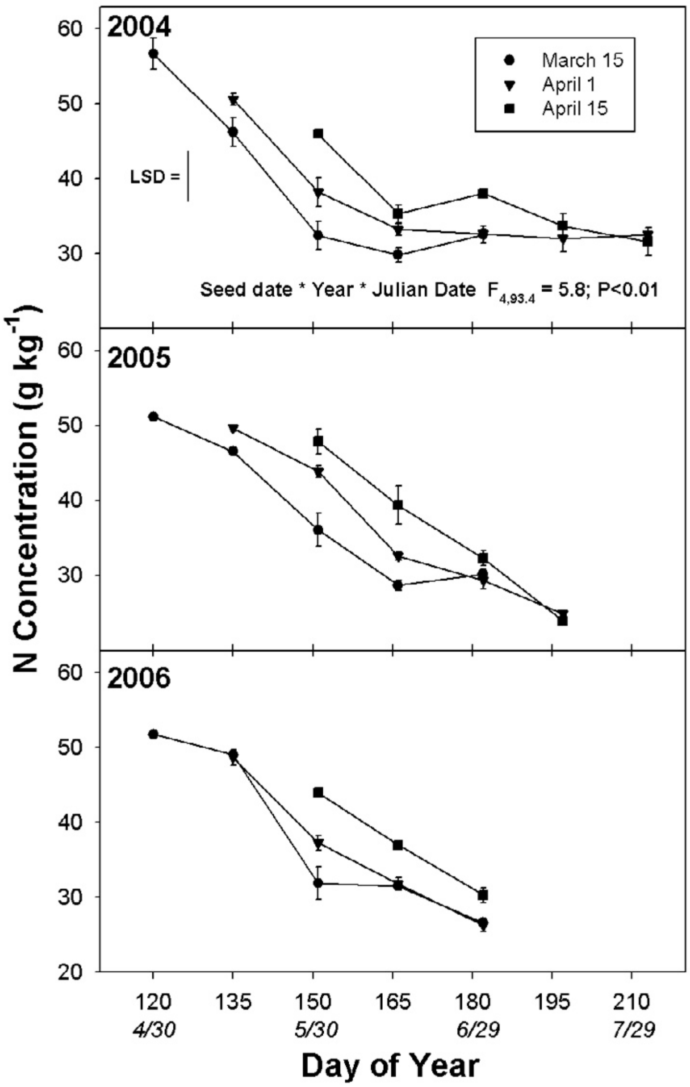

Figure 2. Nitrogen concentrations of grass pea forage during the 2004 through 2006 growing seasons; calendar dates are in italics below day of year. Vertical bars are ± 1 SEM.

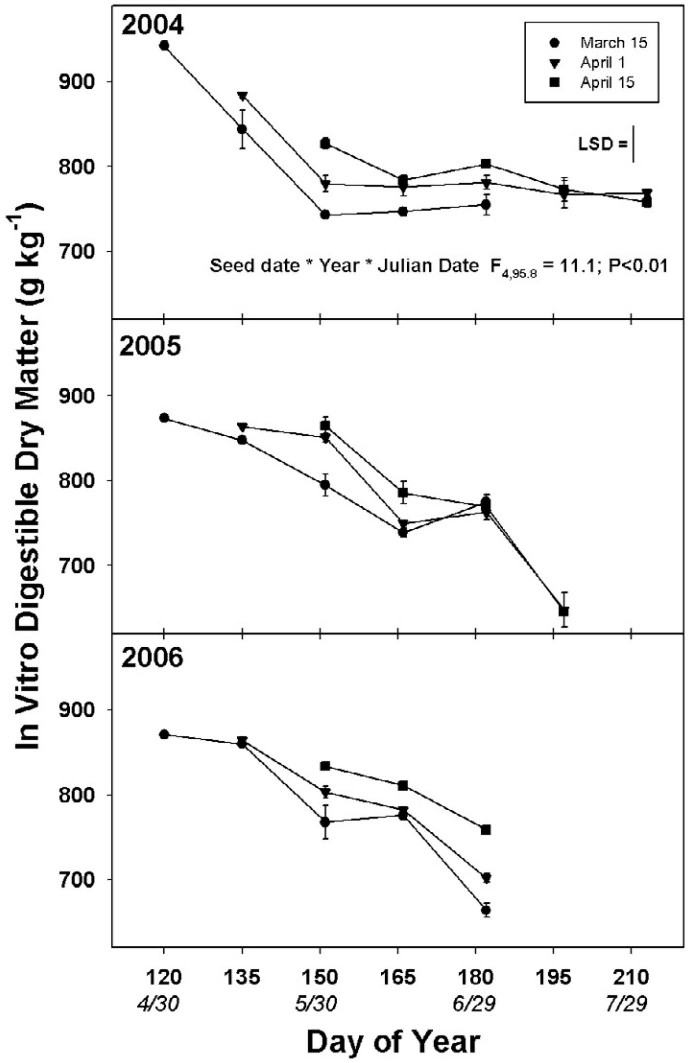

Figure 3. In vitro digestible dry matter of grass pea forage during the 2004 through 2006 growing seasons; calendar dates are in italics below day of year. Vertical bars are ± 1 SEM.

July) in 2004; to 157 kg N ha^{-1} over 75 d (May through early July) in 2005; and to 115 kg N ha^{-1} over 60 d (May through June) during 2006.

The greatest amount of accumulated N in grass pea forage in the DOY × planting date interaction (Fig. 4B) was recorded on DOY 195 of the 1 April planting date (153 kg N ha^{-1}). A group containing observations from the 15 March (DOY 165, DOY 180), 1 April (DOY 180), and 15 April (DOY 195, DOY 210) planting dates had the second-highest amounts (124 to 135 kg N ha^{-1}) of aboveground N. Aboveground N accumulated in grass pea forage in similar fashions under the 15 March and 15 April planting dates, attaining maximum amounts and leveling off. Aboveground N in grass pea forage under the 1 April planting date increased to a maximum, then declined with physiological maturity of plants. Aboveground N increased: to 135 kg N ha^{-1} over 45 d (May through late July) under the 15 March planting date; to 153 kg N ha^{-1} over 60 d (May through early July) under the 1 April planting date; and to 125 kg N ha^{-1} over 45 d (May through June) under the 15 April planting date.

DISCUSSION

Previous studies have identified grass pea for its adaptability to a variety of farming systems in different regions of the world. These systems range from subsistence farming in eastern Africa to rice-based systems in parts of Asia (Campbell, 1997), with growing conditions ranging from cool and arid to humid and tropical. Such a range of farming systems and environments highlights the level of adaptability that exists for planting and growing grass pea, including a range of both arid and wet conditions. This level of adaptability also highlights the responses noted within this study.

Date of planting was reported as important to grain production in cool-season annual legumes. Machado et al. (2003) reported the highest grain yield of chickpea (*Cicer arientinum* L.) in eastern Oregon was produced when planted in early April, while planting after April substantially reduced yield. Late planting of chickpea resulted in smaller plants and late-formed flowers and pods. Increases in flower and pod abortion also occurred if flowering and pod set coincided with hot, dry weather. In contrast, the lack of planting date effects in our study indicated conditions during the growing season were more important for producing aboveground biomass. Biomass produced by grass pea during the three years was variable, differed in length of growing season, and was related to the amount and timing of precipitation. Biomass accumulated in 2004 and 2006 was similar (3900 and 3500 kg DM ha^{-1}, respectively), but grass pea continued to produce forage through the end of July 2004. This extension of the growing season was related to above-average precipitation in June and July. In contrast, precipitation received in 2006 was below average in all months except April. The greater amount of biomass generated in 2005 appeared related to above-average precipitation at the end of the growing season and to below-average temperatures.

The dry conditions encountered during this study limit the scope of inference generated from the results. Responses to growing conditions during normal or wet years cannot be fully addressed, nor is it clear that grass pea would outproduce other cool-season annual legumes with increased precipitation. No information on grass pea response to moisture regimes exists for the Great Plains. However, water use efficiency by grass pea was among the highest in a set of annual cool-season legumes grown in Saskatchewan, Canada (Biederbeck and Bouman, 1994). Grass pea has been used as a source of N in rotation with rice (*Oryza sativa* L.) across Asia (Campbell, 1997). Studies in tropical India and Bangladesh reported high levels of production in different agronomic systems (Gowda and Kaul, 1982; Rathod, 1989). It can be surmised that grass pea will produce greater amounts of biomass under wetter growing conditions than were recorded during this study.

Definitive statements related to responses of N concentration and IVDDM are difficult to ascertain because of the interactions that existed among years, seeding dates, and DOY. The most consistent responses were the declines in both N concentration and IVDDM with advance of the growing season. However, the rate and duration of decline changed among years and with date of seeding. While amounts declined to a stable level within 30 d in 2004, both N concentration and IVDDM continued to decline during 2005 and 2006. These responses reflect the effect of amount and timing of precipitation and air temperature during the growing seasons. Further, reductions in N concentration with length of season may be related to dilution within the accumulating biomass, and translocation of N to pod formation. Although both quality parameters declined with length of season, N concentration and digestibility were still largely above 30 g N kg^{-1} and >700 g kg^{-1} IVDDM. These levels indicate grass pea could provide much of the nutritional requirements for most classes of beef cattle during April through June (Subcommittee on Beef Cattle Nutrition, 1995).

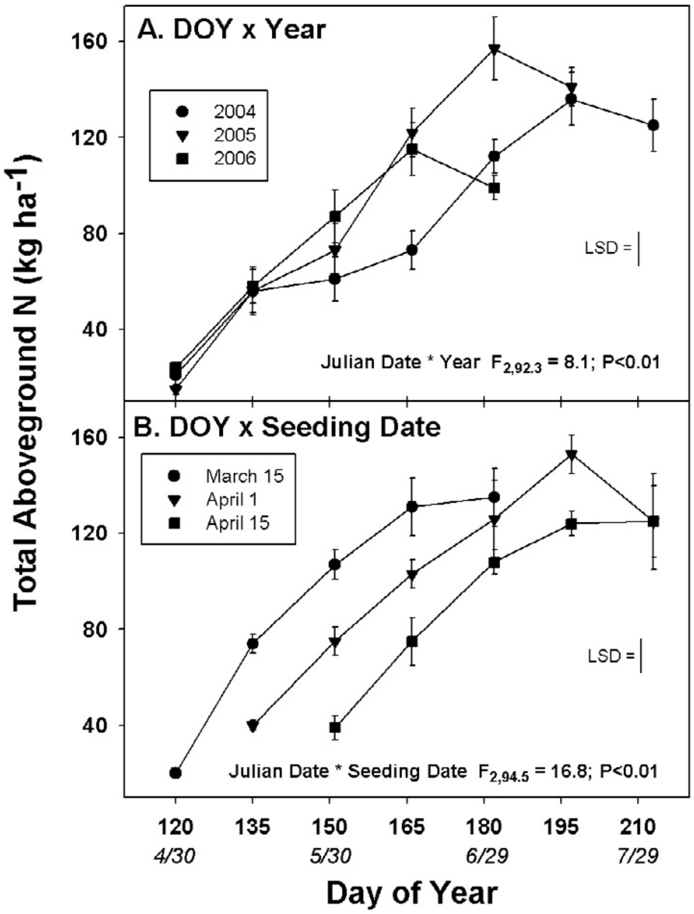

Figure 4. Total aboveground N in grass pea forage: (A) during 2004 through 2006 and (B) in response to three planting dates; calendar dates are in italics below day of year. Vertical bars are ± 1 SEM.

A range of planting dates are available for grass pea that allow accumulation of both aboveground N and biomass. However, there are limits on how late planting can occur. An experiment near our study site, in which grass pea was interseeded with *Eragrostis tef* L. in early May, produced <500 kg ha^{-1} of grass pea forage (B. Northup, unpublished data). Grass pea effectively flowered and began pod set within 30 d of emergence due to rapid accumulation of GDD in June and early July. Earlier planting dates allow for longer growing seasons, which would be advantageous in using any spring-planted legume. Mid-March through early April planting dates would be more effective in using grass pea as a cover or forage crop in the SGP.

While grass pea generated useful amounts of biomass with high N concentrations in relatively short periods of time, the application and effectiveness of this novel legume within cropping systems of the SGP will be an issue. Little information exists on the function of grass pea as a cover crop in the Great Plains. The only reports of grass pea as a cover crop were limited to the northern Great Plains, under dry and variable growing conditions. Grass pea produced between 2100 and 4100 kg ha^{-1} yr^{-1} aboveground biomass over a 6-yr period, but amounts of N in biomass were not reported (Biederbeck et al., 1993; Biederbeck and Bouman, 1994). At peak production in our study, 135, 153, and 125 kg N ha^{-1}, respectively, were present for the 15 March, 1 April, and 15 April planting dates. Similar amounts were produced during the three growing seasons, despite the dry conditions that occurred during the study. These amounts were similar to values reported for other cool-season annual legumes at other locations. Experiments that used hairy vetch (*Vicia villosa* Roth.) and different clovers (*Trifolium* spp.) as green manures preceding summer cereal and forage crops in Georgia and New Mexico generated between 99 and 172 kg N ha^{-1} in forage (Hargrove, 1986; McVay et al., 1989; Guldan et al., 1997). Fertilizer replacement values (FRVs) of these species were reported at 72 to 140 kg N ha^{-1}. The levels of N in grass pea forage during our study fell within the above range. Although not measured, grass pea could approximate the N requirements for a following sorghum [*Sorghum bicolor* L. (Monech)] crop (85 to 100 kg N ha^{-1}) or winter wheat (*Triticum aestivum* L.) crop (100 kg N ha^{-1}) in the semiarid environments of the SGP (Zhang et al., 1998; Redmon et al., 1995). Additional studies are required to define the FRV of grass pea and availability of accumulated N to a subsequent crop.

Grass pea could also provide high-quality forage for grazing. Grass pea forage and its N concentration and digestibility were similar to levels reported in an earlier study, conducted under similar growing conditions (Rao et al., 2005b). Forage produced during this study (3900, 5800, and 3500 kg ha^{-1} in 2003, 2004, and 2005, respectively) could potentially support up to 437, 651, and 393 grazing days by 350 kg stocker cattle (8.9 kg d^{-1} intake). Nitrogen concentrations in the forage (23 to 56 g kg^{-1}) exceeded the daily N requirements (173 g N in 11.5 kg d^{-1} consumed forage) for mature 454 kg beef cows with suckling calves and most weight classes of stocker cattle (Subcommittee on Beef Cattle Nutrition, 1995). Given the high N levels, a potentially effective use of grass pea in grazing systems may be as limit-grazed complementary forage in late spring and early summer, in combination with lower-quality pasture. Grass pea could act as a growing supplement to balance the nutrient requirements of grazing animals and improve utilization of the lower quality forage. Such management would improve both forage quality of the available biomass and N status of the soil. Fixed N within the planted field would be retained (as a green manure), and some portion of the biological N_2 in grass pea would provide a degree of fertilization for the paddocks of low-quality forage. As with FRV, experiments are required to define the potential effects of grass pea as complementary forage on stocker cattle, as well as potential influences on the soil quality of pastures.

CONCLUSIONS

Grass pea has been recognized as an adaptable legume capable of growth in a variety of farming systems, under a range of environmental conditions. This adaptability results in a flexible response to environmental conditions during growing seasons. As such, this study could not identify an optimum spring planting date for grass pea in the SGP, given the 30-d window used here. The rapid accumulation of GDD and rates of maturation under the later planting dates resulted in relatively similar levels of biomass across the planting dates used, under moderate drought conditions. In contrast, environmental conditions during the growing seasons, specifically, the amount and timing of precipitation, did affect biomass production. Alternatively, maximum N accumulation in aboveground biomass was influenced by both growing season and date of planting, although the differences were not large. We conclude that grass pea was capable of generating useful levels of biomass and biological nitrogen across a range of spring planting dates. This flexibility permits grass pea to have merit as high-quality forage during June through July, or as a green manure for inclusion in cropping systems of the southern Great Plains.

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